PTO 05-4286

German Patent
Document No. DE 44 29 684 A1

PROCESS FOR COMPACTION AND SUBSEQUENT WELDING OF ELECTRIC CONDUCTORS
[Verfahren zum Kompaktieren und anschliessenden Schweissen von elektrischen Leitern]

Udo Wagenbach et al

UNITED STATES PATENT AND TRADEMARK OFFICE
Washington, D.C. June 2005

Translated by: Schreiber Translations, Inc.

Country	:	Federal Republic of Germany
Document No.	:	DE 44 29 684 A1
Document Type	:	Document laid open/first publication
Language	:	German
Inventor	:	Udo Wagenbach, Enno Thoms, and Dieter Stroh
Applicant	:	Schunk Ultraschalltechnik LLC, Wettenberg, Federal Republic of Germany
IPC	:	B 23 K 20/10
Application Date	:	August 22, 1994
Publication Date	:	February 29, 1996
Foreign Language Title	:	Verfahren zum Kompaktieren und anschliessenden Schweissen von elektrischen Leitern
English Title	:	PROCESS FOR COMPACTION AND SUBSEQUENT WELDING OF ELECTRIC CONDUCTORS

/1[1]

PROCESS FOR COMPACTION AND SUBSEQUENT WELDING OF ELECTRIC CONDUCTORS

The object of the invention is a process for compacting and subsequently welding electric conductors in a compression space (10) by means of ultrasound. After the conductors are compacted, a measurement that is typical for the compaction is measured or determined from measured values and checked by means of limit values. If the values of the measurement are unallowable, the process for the production of welded conductors is interrupted; if the value of the measurement is allowable, a new desired value is determined for the compaction from values of previous production steps. The limit values are referenced on the new desired values. Thereafter, the process is continued, and the welding is carried out. A characteristic value for the welding is subsequently determined. The determination and evaluation of these values occurs in the same way as with the value for the compaction. /2

[1] Numbers in the margin indicate pagination in the foreign text.

Description

The invention concerns a process for compacting and subsequently welding electric conductors, in particular for the production of transit or final nodes of stranded conductors by means of ultrasound in a compression space, which is adaptable to the conductors, where the conductors to be welded are initially compacted and thereafter welded.

For the purpose of compacting and additionally welding electric conductors, in particular for producing transit and final nodes of stranded conductors, are used ultrasound welding devices, which have sonotrodes for generating ultrasound oscillations. A section of the respective sonotrode forms a first lateral boundary surface, for example, of a compression space that can be adjusted with regard to height and width and is open at the front end. The other boundary surfaces of the compression space can be sections of a multipart counter electrode. Examples of ultrasound welding devices are devices offered under the names RK 2000 or Minic Automatic of Schunk Ultrasound Technology LLC, Wettenberg, Federal Republic of Germany.

In order to comply with today's requirements, it must be ensured that material changes or a change of operators of the

ultrasound welding device do not show an influence on the welded final products.

It is therefore an object of the invention to further develop a process of the kind described above in such a way that, based on the parameters obtained during the work procedures carried out for the production of welded electric conductors, which are decisive for the properties of the produced products, it can be automatically ensured that the welded products are within allowable narrow manufacturing tolerances.

The object is attained pursuant to the invention with a process of the kind described above in that, after the conductors are compacted, a value that indicates the compaction measurement is measured or determined from measured values, and the same is compared to at least one predetermined upper and lower counter value based on a desired value that lies outside of the range delimited by the limit values, if the value lies outside of the range delimited by the limit values, the welding is not carried out, and if the value lies within the range delimited by the limit values, the value is allocated, together with the values determined during previous work procedures, to a new desired value for checking the subsequent compaction work procedures and the welding is carried out and/or a measurement

that is decisive for the welding procedure is carried out or is determined from measured values and compared at least to one upper and lower limit value based on a desired value, and an error is indicated if the value lies outside of the range delimited by the limit values, and if the value lies within this range, the value is allocated, together with the values determined during previous work procedures, to a new desired value for checking the subsequent compaction work procedures. With this process, the desired values, with which the mode of operation of the ultrasound welding device is checked during the course of the production process, are continuously adapted to the respective conditions by means of the actual values measured during successive production work steps or processes. In this way is provided for the first time the possibility of a dynamic adaptation of the parameters that are characteristic for the compacting or welding to the previous compaction or welding. A further improvement of the production tolerances occurs thus as a consequence of a dynamic desired value adaptation. A dynamic desired value adaptation to the actual process variation can also be carried out.

In this way are achieved uniform welding results. In this way is also prevented the formation of defective products that

remain undetected when there are deviations from the necessary production conditions.

In a preferred embodiment, the conductors are impinged with ultrasound during compaction. The strength of this ultrasound impingement is less than the strength required for the welding of the conductors. The additional ultrasound treatment during the compaction causes the conductor to be more highly compacted, which is particularly advantageous for the subsequent measurement and welding.

In other words, by means of a so-called ultrasound prepulse or a prepulse sequence is achieved an uniformization of the compaction.

The ultrasound treatment of the conductors during the compaction has an independent inventive content, since it leads to an improvement in the subsequent welding also without the described desired value adaptation.

As measurement that decisively influences the welding procedure can be selected the cross section of the compression space, which can be occupied or filled out by the conductors during or after the conclusion of the welding procedure. However, in particular the height or the width of the compression space can be selected as decisive parameter.

In a further preferred embodiment, the measured value or the value determined from the measured values during or after the conclusion of the compaction and/or the measured value or the value determined from the measured values during or after conclusion of the welding measurement are compared respectively to a fixed predetermined upper and lower limit value and to a further upper and lower limit value, which is comprised by the desired value for the compaction or welding calculated for the respective work step of the production process plus an allowable positive or negative tolerance value. The fixed predetermined limit values, which will also be called in the following outer limit values, are determined and stored during the setup of the ultrasound welding device provided for carrying out the process. The limit values formed with the aid of the desired values, which will also be called in the following inner limit values, allow the detection of small deviations between sequential production procedures. From these can be drawn conclusions concerning tendencies induced by the material or the device that have an undesirable influence on the quality. Long-term influences, for example, can be monitored, whereby preventive measures for precluding a device failure or for ensuring a constant product quality can be met.

However, especially small errors can be safely detected by /3

means of the process pursuant to the invention.

The desired values can be preferably calculated as arithmetic mean values from several values of previous production steps. The number of measured values to be utilized for determining the mean values can be between a few and many values. In the production step that directly follows the setup of the ultrasound welding device can be utilized the desired values determined during setup.

Error messages are suitably generated if the outer or inner limit value is exceeded or underexceeded and the values measured during the defective work procedure are stored for subsequent evaluation.

Further details, advantages and features of the invention result, not only from the claims and the features that are disclosed therein, but also from the subsequent description of a preferred exemplary embodiment disclosed in the drawings, wherein:

Fig. 1 shows a cutout of an ultrasound welding device with a changeable compression space,

Fig. 2 shows a flow diagram of a process carried out with the device pursuant to Fig. 1 for welding in particular electric conductors, and

Fig. 3 shows a time diagram of a typical sequence of actual and desired values of an ultrasound welding device pursuant to Fig. 1 during the production of mutually welded stranded conductors in succeeding production steps.

In Fig. 1 is shown a cutout of an ultrasound welding device for welding electric conductors, insofar as a compression space (10) that is adjustable to the conductors to be welded is affected. The ultrasound welding device itself can have a configuration that corresponds essentially to the device RK 2000 or Minic Automatic of Schunk Ultrasound Technology LLC, Wettenberg.

The compression space (10) has in the exemplary embodiment a rectangular cross section and is open at the front end in order to weld the same to the conductor. Compression spaces with other cross sections are also possible, of course, such as in particular a trapezoidal cross section.

The compression space (10) is enclosed on the sides by boundary surfaces (12), (14), (16) and (18), which are delimited on one side by a section of a sonotrode (20) and on the other side by a multipart counter electrode (22) such an anvil.

The multipart counter electrode (22) comprises a slide bar (24), which can be displaced along the boundary surface (12) made available by the sonotrode (12), and which constitutes the

lateral boundary surface (14). The direction of movement of the slide bar (24) is indicated by the arrow (52). Opposite the slide bar (24) is arranged a second part (26) of the counter electrode (22), which can be displaced (S1) parallel to the boundary surface (14), that is, vertical to the sonotrode surface (12). The second part (26) displaceably accommodates a section (28) that can be designated as a lug, which can be moved in correspondence with the arrow (S3) parallel to the surface (12).

The space enclosed by the boundary surfaces (12), (14), (16) and (18) is modified in dependence upon the respective conductors to be welded.

The compression space (10) is adjusted for the compaction of the inserted conductors, that is, for compressing these to a previously set height and width ratio. This is symbolized in Fig. 1 by means of the rectangles of different sizes drawn in the compression space.

The slide bar (24) is connected to a drive (36), in particular a pneumatic or hydraulic drive, by means of which the slide bar (24) can be moved in the direction of the arrow S2 and vice versa. The part (26) of the counter electrode (22) is connected to a drive (38), which can also be configured preferably as a pneumatic or hydraulic drive.

The part (26) can be displaced in the direction of the arrow S1 and vice versa by means of the drive (38). The slide bar (24) is furthermore connected to a position sensor (40), with which the position of the slide bar (24) with reference to a parked position can be detected.

A control device (46), for example, a programmable memory control, is connected to the position sensors (40), (42), the sonotrode (20) set for ultrasound, as well as the control elements (which are not shown in detail) for the drives (36), (38). A monitor (48) is connected to the control device (46).

The height (h) and/or the width (b) of the compression space (10) is determined by means of measuring values generated by at least one position sensor, in the exemplary embodiment the position sensors (40), (42), and evaluated by the control device (46). Different parameters are allocated to different cross sections or different heights or widths of the compression space (10), and these parameters are adjusted with the ultrasound welding device in order to weld the conductors. They are welding parameters such as the welding energy, welding amplitude, welding time, and welding pressure.

During welding is modified in particular the height (h) of the compression space (10), while the width (h) remains the

same, since after concluding a precompression on the conductors, for example, the slide bar (24) is stopped.

A force sensor (50) can also be connected to the part (26), with which is measured the force exerted by the part (26) on the conductor placed in the compression space (10). The force sensor is also connected to the control unit (46). An indirect measurement by means of a pressure control can of course also be carried out.

With the above-described device are compacted the conductors placed in the compression space (10) by moving the slide bar (24) and the part (22) in such a way that the cross section of the precompression space (10) is reduced. The forces for the adjustment of the cross section are produced by the control unit (46) via signals going out to the drives (36), (38), whereupon the respective cross section of the precompression space to be adjusted is determined by the control device (46) via the measured values generated by the position sensor (40), (42).

The cross section or the height or the width of the precompression space (10) at the end or after the conclusion of the precompression is accordingly a measurement of the precompression measurement, that is, the geometry of the

precompression space can be used or evaluated as precompression measurement or compaction measurement. Since, for example, only/4 the width (b) and/or the height (h) of the precompression space (10) can be changed, the cross section can be rapidly and easily determined.

If a force sensor (50) is present, also the force exerted on the conductors can be used as precompression measurement.

During the welding procedure, the cross section changes again only with regard to the height or width of the precompression space, whereupon the cross section existing at the end or after conclusion of the welding is a measure of the quality of the welding of the conductor.

Since the compaction measurement and the welding measurement can be adjusted by means of actuators, such as slide bars or the part (26), corresponding desired values are inputted in the control unit (46). Fixed upper and lower limit values for the compaction measurement and welding measurement are furthermore inputted in the control unit (46). These limit values are called outer limit values. Further limit values, which are called inner limit values in the following, and which fix respectively an upper and a lower limit for the compaction measurement and/or the welding measurement during the production of welded conductors, are determined with the control unit (46).

The process, which will be described in the following in connection with the flow diagram of Fig. 2, is carried out with the above-described device.

In a first step (52), which is called "Start" in Fig. 2, is set into motion the ultrasound welding device. Thereafter, a specific stranded conductor combination is placed thereafter in the compression space (10) in a step (54). The production process of the welded conductor is started subsequently in a step (56). The compression space (10) is closed thereafter in a step (58) by driving or moving the slide bar (24) and the part (26) in the directions identified by means of the arrows (S2) and (S1). In Fig. 2, step (58) is indicated with "Close Tools."

An ultrasound pulse or a sequence thereof is generated during step (58) or thereafter in order to further compact the conductors. In this way occurs in the actual sense an uniformization of the compaction (step (60)). The compaction measurement of the geometry of the compression space, which is determined by means of the knowledge of the width and/or height or another specific measure, is determined after the compaction in an additional step (62). A step (64) follows, in which the determined compaction measurement is compared to an upper and a lower outer limit value.

The upper and the lower outer limit value are determined during setup of the ultrasound welding device. The limit values determine the outer limits of the pressure measurements. The compaction measurement is compared thereafter to an upper and lower “inner” limit value. The upper and the lower “inner” limit value are determined from the desired value of the pressure measurement plus a first tolerance value and minus a second tolerance value. The tolerance values must not be of equal size.

A step (66) follows if an upper outer or inner limit value is exceeded or a lower outer or inner limit value is underexceeded, in which an optical and/or acoustic error message is generated, which leads to a step (68) in which the tools are open, so that the production process is no longer continued. The conductor can be taken out of the ultrasound welding device. With the opening of the tools or thereafter, the error is written into a statistic, which is available in a database in the control unit (46) in a step (70). Before the ultrasound welding device can start again, the error must be acknowledged or checked and if required corrected if the outer limits of the process have been exceeded.

If the compaction measurement lies within the ranges delimited by the limit values, then follows a process step (74)

in which a new desired value is determined from compaction measurements that were measured and stored in previous n-production procedures or steps and the just determined value. In this compaction measurement is therefore included the just ended production procedure. The desired value is determined, for example, as arithmetic mean value for the testing of the next production procedure of welded conductors. The number n amounts, for example, to between 3 and 50. After the setup of the ultrasound welding device, if no compaction measurement was measured or determined, the setup measurement is predetermined as desired value.

The step (74) is followed by a step (76), in which the welding is carried out. During this step, the control unit or device (46) adjusts the allocated welding parameters such as the welding energy, welding amplitude, welding time, and welding pressure. The welding parameters are maintained during the following step (78) identified in Fig. 2 as energy control. After the step (78), it is checked in step (80) if the time provided for the energy supply is exceeded. With the step (78) is also pulsed a timing element. If the allowable time is exceeded, the step (66) is bypassed.

If the time limit for the energy supply has been maintained, it is preceded to a step (82), in which the welding

measurement is determined. The welding measurement is, as indicated above, the geometry measured at or after the conclusion of the welding procedure based on the height and/or width of the precompression space (10), which is changed during the welding.

The determination of the welding measurement occurs like the determination of the compaction measurement by means of the measured values generated by the position sensors (40), (42). A step (84) follows, in which the determined welding measurement is compared to limit values. An upper and a lower "outer" fixed limit value are predetermined. The two outer limit values are determined during the setup of the ultrasound welding device. The welding measurement is furthermore compared to an upper and a lower "inner" limit value. The inner limit values are determined from the desired values of the welding measurement plus a first tolerance value and minus a second tolerance value. If an upper limit value of the determined welding measurement is exceeded or a lower limit value is underexceeded, then the step (66) is carried out as next step. The tolerance values must not be identical.

If the welding measurement lies within the ranges delimited by the outer and inner limit values, then the production process is continued with step (86), in which a new desired value for

the welding measurement is calculated from n values as arithmetic mean value. The n values refer to the latest determined value and the welding measurement determined in the previous production steps. After calculating and storing the new desired value, the ultrasound welding device is released in the following step (88) by opening the tools, that is, by means of the opening of the precompression space (10) for the removal of the welding product. In a further step (90), the carried out welding is taken into consideration in the counter that indicates the number of acceptable weldings. The parameters available during the welding are written into a statistical database.

The production process is concluded in this way, which is indicated in Fig. 2 with the step (92) labeled with "End." A new production process starts with the step (54) after the removal of the welding product in the operationally ready ultrasound welding device.

Fig. 3 shows, for example, several compaction measurements in different production steps, which comprise at least the steps (54) through (90), in dependence upon the timely execution of the steps. The values of the compaction measurements K are entered in the ordinate direction, while the number n of the compactions is represented in the abscissa direction. The

compaction measurements (94), (96), (98), (100), (102), (1040, (106), (108), (110) are shown as actual values, and can be connected to each other by means of a mean curve (112). An outer upper limit value (114) and an outer lower limit value (116) are determined as comparison values by means of the arrangement of the machine and are constant. From the arithmetic mean values of n compaction measurements (with n being, for example, 3...50), which are determined in successive production steps, are determined by means of a tolerance measurement, which is added to the mean values or is subtracted therefrom, an inner upper limit (118) and a lower inner limit (120), to which are allocated respectively the same time point as the compacting measurement. A desired value (122) is set at the start of the process by means of the arrangement of the machine. Errors can be better detected with the use of the inner limit values despite the long-term influences on the production process.

The above process allows a continuous checking of the production processes of welded conductors or stranded conductors. The production processes are controlled by means of the control device (46).

Patent Claims

1. A process for compacting and subsequently welding electric conductors, in particular for producing transit or final nodes of stranded conductors by means of ultrasound in a compression space (10) that can be adapted to the conductors, where the conductors to be welded are initially compacted and thereafter welded, wherein after the compacting of the conductors, a value that indicates the compaction measurement is measured or determined from measured values and compared to at least one predetermined upper and lower limit value based on a desired value, and the welding is not carried out if the value lies outside of the range delimited by the limit values, and if the value lies within the range enclosed by the limit values lies within the range delimited by the limit values, the value is allocated with the values determined during previous work procedures to a new desired value for checking the subsequent compacting work procedures, and the welding is carried out and/or one measurement that is representative of the welding procedure and is available during or after the conclusion of the welding is measured or determined from measured values, and is compared at least with an upper and lower limit value based on a desired value, and

an error is indicated if the value lies outside of the range delimited by the limit values, and if the value lies within this range, the value is allocated with the values determined during previous work procedures to a new desired value for checking the subsequent compaction work procedures.

2. The process particularly of claim 1, wherein the conductors are impinged with ultrasound whose strength is weaker than the strength required for welding during the compaction.

3. The process of claim 1 or 2, wherein the value that is decisive for the measurement of the compaction is the cross section of the compression space after conclusion of the compaction or a value proportional to the cross section.

4. The process of claim 1 or 2, wherein the measurement that is decisive for the welding procedure is the cross section of the compression space at the conclusion of the welding or a measurement that is proportional to the cross section.

5. The process of one or several of the preceding claims, wherein the value measured during or after the conclusion of the compaction or determined from measured values and/or the value measured during or after conclusion of the

welding or determined from measured values are compared to a fixed predetermined upper and a lower limit value and to a further upper and a lower limit value, which is respectively comprised of the desired value of the compaction or welding applicable in the respective work step plus an allowable positive or negative tolerance value.

6. The process of one or several of the preceding claims, wherein the desired values are preferably calculated as arithmetic mean values of several values of previous production steps.

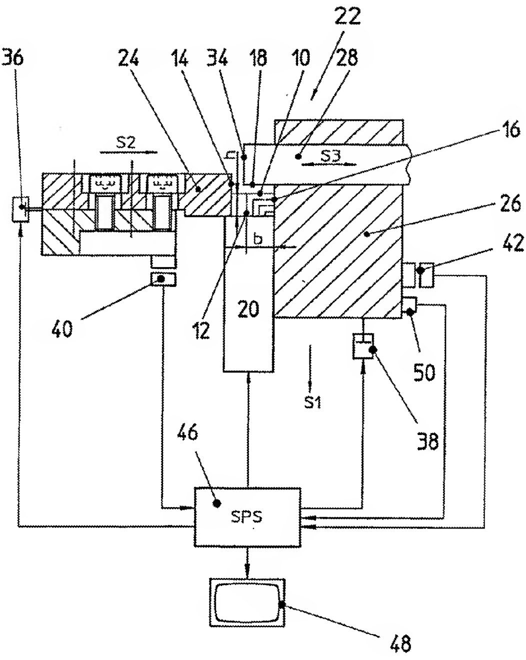
7. The process of claim 6, wherein the number n of values of previous production steps, which are used for the desired value determination, lies preferably between 3 and 50.

8. The process of one or several of the preceding claims, wherein the time period of the application of the welding parameters during welding is compared to a predetermined time period and an error message is generated if the predetermined time period is exceeded.

9. The process of one or several of the preceding claims, wherein an error message is stored or taken into consideration in a statistical database. /6

10. The process of one or several of the preceding claims, wherein if values of the compaction and welding lie within the upper and lower limit values, the welding procedure is stored or taken into consideration in a statistical database and the welding parameters are stored. /7

Fig. 1



Ablauf einer Schweißung mit Qualitätsüberwachung, Vorschall und dynamischer Sollwertanpassung

Fig.2

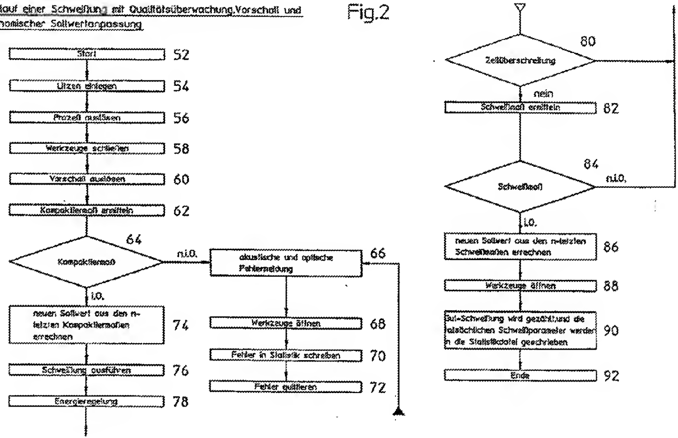


Fig.3